91602
new 82-10

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research If
Reproduced in Whole or in Part

ontario hydro
research division

EXECUTIVE SUMMARY

REPLACEMENT OF USED, PARTIALLY DECAYED DOUGLAS FIR CROSSARMS - PRELIMINARY TESTS

D.A. BLACK and G.A. SUBJECT

Mechanical Testing and Development Section
Mechanical Research Department

A limited number of used Douglas Fir crossarms were evaluated. The purpose was to establish suitable methods for determining when partially decayed arms need replacement. The testing included visual examination, moisture measurements, ultrasonic testing, probing with a penetration device and failure testing.

The testing showed that the penetration device was more practical than other methods in determining the depth of rot. The loss of strength follows the reduction of cross-section due to decay. The strength varies as the square of the depth of the arm. The penetration tool seemed to measure the depth of decay reasonably well. The number of samples was quite limited and it was not possible to establish accurate statistics on the condition of the arms presently in service. Sound wood was found to retain its original properties. The report recommends further investigations with full length crossarms.

job	file	date	report no.
740624-180-20231	824.11	June 4, 1985	85-89-K

91602
new 82-10

ontario hydro
research division

TO Mr. A.E. Martin
Manager
Transmission Lines
Transmission Operations

REPLACEMENT OF USED, PARTIALLY DECAYED DOUGLAS FIR CROSSARMS - PRELIMINARY TESTS

D.A. Black and G.A. Subject

A limited number of used crossarms were examined using ultrasonic testing, a penetrating probe and mechanical tests. The tests were done to determine if there is a suitable method for determining when crossarms should be replaced.

1.0 INTRODUCTION

Two sectioned, partially decayed wood crossarms removed from service were supplied for tests and evaluation. One section of a failed arm was presented for examination. Hundreds of untreated Douglas Fir crossarms were placed in service several decades ago. These arms are showing various degrees of decay. As the replacement of these arms is expensive, a method for determining which arms need replacement is required. Total failure of a crossarm could cause a loss of electrical service.

2.0 SAMPLES

A single 4 x 8 x 24 ft Douglas Fir crossarm was supplied in 4 sections of various lengths, (see Figure 1). This arm was removed from a two-pole structure and supported 3 insulator strings. A single section of a second, shorter crossarm was supplied, (see Figure 2). This arm supported a single insulator string between two poles.

A very short section of a failed crossarm was supplied, (see Figure 3). These untreated Douglas Fir crossarms were estimated to be approximately 35 years old. However, their actual history was not supplied.

job	file	date	report no.
740624-180-20231	824.11	June 4, 1985	85-89-K

3.0 TESTS AND PROCEDURES

The crossarms were measured, photographed and the ends dressed. Knot sizes and locations were recorded. Loading points were established for failure testing. The sections were load tested such that the stresses were in the same direction as in service. The deflection was also recorded to determine the modulus of elasticity.

Non-destructive tests were also performed to determine if a simple evaluation technique could be found. An ultrasonic tester was used in an attempt to measure the modulus of elasticity and detect internal decay pockets. Additional tests were made with a hand held penetration device. Tests on a new crossarm section were used for comparison with both the ultrasonic and the penetration device.

Before load testing, moisture measurements were made.

4.0 TEST RESULTS AND OBSERVATIONS

The crossarms were extensively weathered with signs of surface decay. Figures 4 through 11 show the dimensions, knot sizes and loading points for the 24-foot crossarm.

Figures 12 through 18 show the appearance of the dressed ends of the crossarms. In general, the internal condition of the wood was excellent. The growth rings and surface luster indicated that the wood was not brash. Brash wood was found in one crossarm section. The growth rings are difficult to see and the surface is dull and lifeless, (top of Figure 18).

Ultrasonic testing (Figure 19), showed some increase in the transit time when the probes were placed near either the top or the bottom of the crossarm. New arm material did not show this increase in transit time. An increase in the transit time indicates a decrease in the modulus of elasticity. It was difficult to obtain good coupling between the probes due to the weathered wood surfaces. The test results using the ultrasonic tester are given in Table I.

Test results with the penetration device, (Figure 20), appeared to be more useful than with the ultrasonic tester. The needle would penetrate up to 6 mm in new Douglas Fir. Depths up to 27 mm were recorded in the failed arm, (Figure 3). The strength of the crossarm varies as the square of the depth of the arm. This device, although more practical than the ultrasonic tester is not commercially available and was constructed by Ontario Hydro. A suitable instrument could easily be designed and fabricated for field use.

Load testing, (Figures 21 and 22), failed to give strengths equivalent to a full sized arm. When the arms were cut into short lengths the mode of failure was longitudinal shear. Tension or compression failure in bending were not observed until after the shear failure. When failure in bending did finally occur, there was considerable splintering. This shows that the wood is not brash. Because of the shear failure, determining the modulus of rupture was not practical. The values measured (8,700 to 14,100 MPa, see Table I) were near the expected values of 8,300 to 14,000 MPa.

The moisture content ranged up to 17%, which is higher than the 12% expected for air dry timbers. A top cover on the crossarms would reduce the moisture content and the rate of decay significantly. Decay pockets would tend to collect and hold water for long periods of time. Decay will not occur in wood with a moisture content below 18%. The moisture content of the arms when on the pole must have been higher than our measurements since considerable time had lapsed before moisture readings were taken.

5.0 CONCLUSIONS

Only crossarms which are undependable should be replaced to minimize the cost. Estimating the depth of decay appears to be the best indication of remaining strength.

Two devices were used to evaluate the condition of the wood. The ultrasonic testing device used measures the time for a pulse to traverse the arm. The device tested was not very practical because the transducers were difficult to couple with the wood. The equipment was also somewhat bulky. A penetrating device which was pushed into the top surface was more practical for field use. However, the tip was easily bent and the device is not commercially available. It may be possible to use a CSA powder activated fastening tool instead of the hand held penetrating device.

The wood crossarms tested appear to have a modulus comparable to book values after an allowance is made for decay. Therefore, the wood probably has strength comparable to new wood. Since the strength varies as the square of the depth a 25 mm loss of depth represents a 25% loss of strength. Replacement of the arm should be made where the depth of decay exceeds this amount.

Alternative methods may also be useful. It may be practical to nail 1 x 6 pieces along the top of the crossarm. This would act as a roof and prevent water from entering the top of the arm. Some of the lost strength would also be restored. The wood cap would require grooves on the bottom face to prevent water from running under the cap. Plastic strips may also be worth investigating. If water can be prevented from entering the top of the arm, the decay will be arrested. Heavy tar coatings may be useful in coating the top of the arm, but these may not stick very well. The top of the arm may also be treatable with wood preservative.

6.0 RECOMMENDATIONS

1. Obtaining additional samples that are full length would provide more useful data on the remaining strength.

2. Some of the repair possibilities should be investigated.

3. Improving and testing the penetration device may be worth while. The devices could be manufactured for field use.

4. Using an ultrasonic type tester is probably not practical because of the rough wood surface.

Approved:

G.J. Clarke
Manager
Mechanical Research Dept

Submitted

D.A. Black
Engineer
Mechanical Testing and
Development Section

G.A. Subject
Technician
Mechanical Testing and
Development Section

DAB:GAS:sf

TABLE 1

PENETRATION AND ULTRASONIC TESTING OF USED AND NEW CROSSARM SECTIONS

SIDE VIEW

25% Depth - O Top

50% Depth - O Centre

75% Depth - O Bottom

ULTRASONIC TEST LOCATIONS

TOP VIEW

o - 25% Width
o - 50% Width
o - 75% Width

NEEDLE PROBE TEST LOCATIONS

Timber Section No	Test Location	Ultrasonic Reading (µSec) Top	Centre	Bottom	Needle Penetration (mm) 25% Width	50% Width	75% Width	Average Moisture	Remaining Depth mm	Modulus of Elasticity MPa	Comments
24-foot arm (Sample 1)											
1	Centre of Section	57	47	55	11	13	21				
	250 mm Right of Centre	-	-	-	11	17	24	11 to 16%	183	8 200	Diagonal corner knots at maximum moment.
	250 mm Left of Centre	-	-	-	11	16	27				
2	Centre of Section	54	46	54	19	11	16				
	180 mm Right of Centre	54	49	54	11	11	16	17%	186	14 100	Clear of knots.
	180 mm Left of Centre	57	49	55	10	10	21				
3	Centre of Section	56	49	56	10	10	14				
	230 mm Right of Centre	52	48	55	13	10	19	13 to 17%	186	10 400	Diagonal knot near maximum moment.
	230 mm Left of Centre	54	49	56	13	13	22				
4	Centre of Section	51	46	52	11	11	11				
	200 mm Right of Centre	54	47	55	11	19	16	14 to 16%	187	≈13 700	Fair size knot fairly close to max moment.
	200 mm Left of Centre	-	-	-	11	11	13				
Short Arm (Sample 2)											
1	-	-	-	-	-	-	-	11 to 17%	≈193 (max)	≈ 8 960 (min)	Deep pocket of decay in centre dimension not corrected for decay.
New Arm											
1	-	46	46	46	6	6	6				
Failed Arm (Sample 3											
1	-	-	47	-	-	-	-				

NOTE: Subtract 6 mm from all penetration readings.

FIGURE 1

Four sections of the 24-foot crossarm showing the location of the three insulator strings. The insulators were hung from the U-bolts (centre and both ends). The crossarm was attached to two poles using through bolts. The poles were midway between the centre and end U-bolts. The highest stresses occur at the poles with the top face (left side) in tension. Visually, linemen would have some difficulty in estimating the loss in strength of this crossarm.

FIGURE 2

Section of shorter crossarm with insulator string in the centre and wood poles both ends. The left end was mounted to the pole. The highest stresses occur in the centre of the crossarm with the top face in compression. It is obvious that this arm needed replacing.

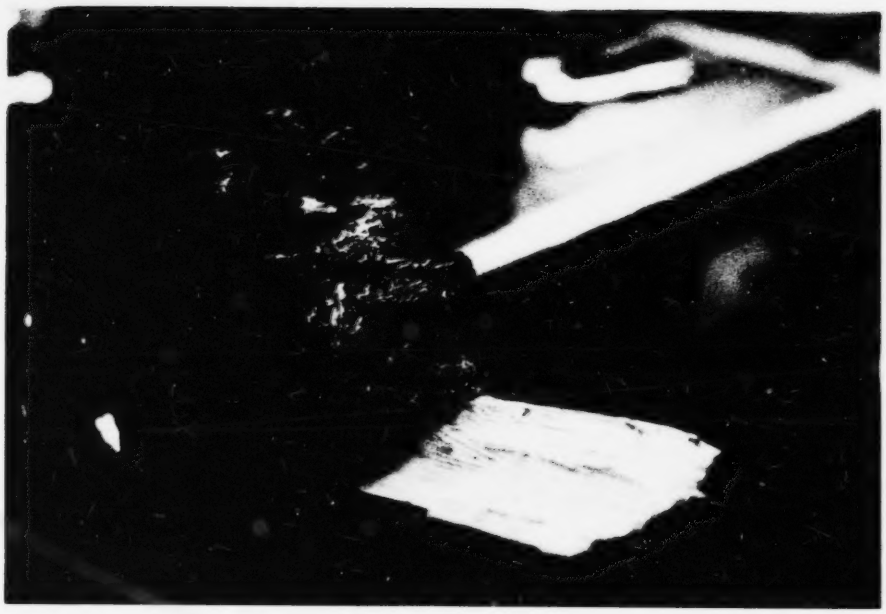


FIGURE 3

Section of crossarm which failed in service. The break is quite short and characteristic of a compression type failure and a brash failure at the top where there is extensive decay.

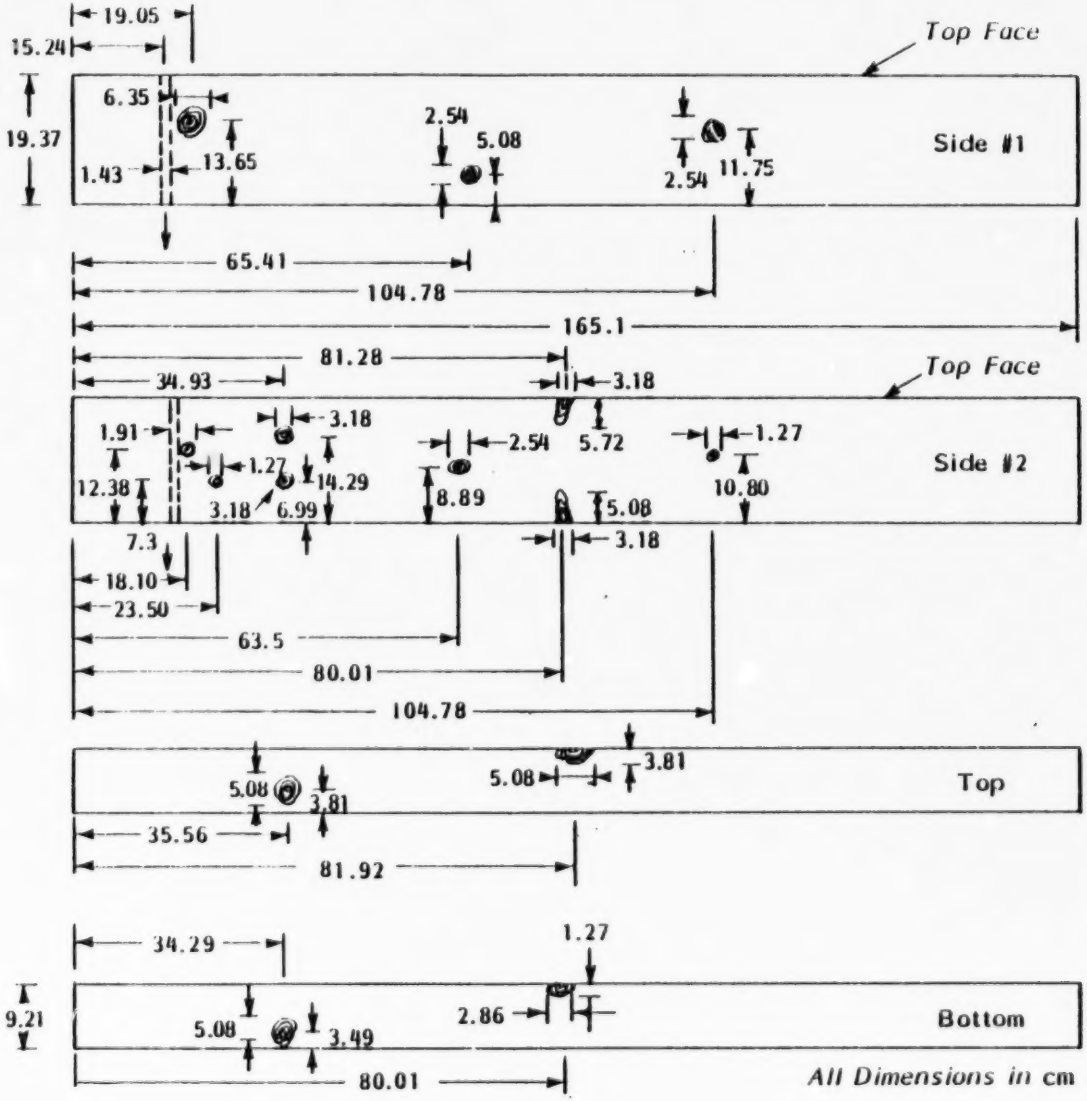


FIGURE 4

SECTION #1 - DIMENSIONS AND KNOT LOCATIONS FOR THE FIRST SECTION OF THE 731.52cm CROSSARM

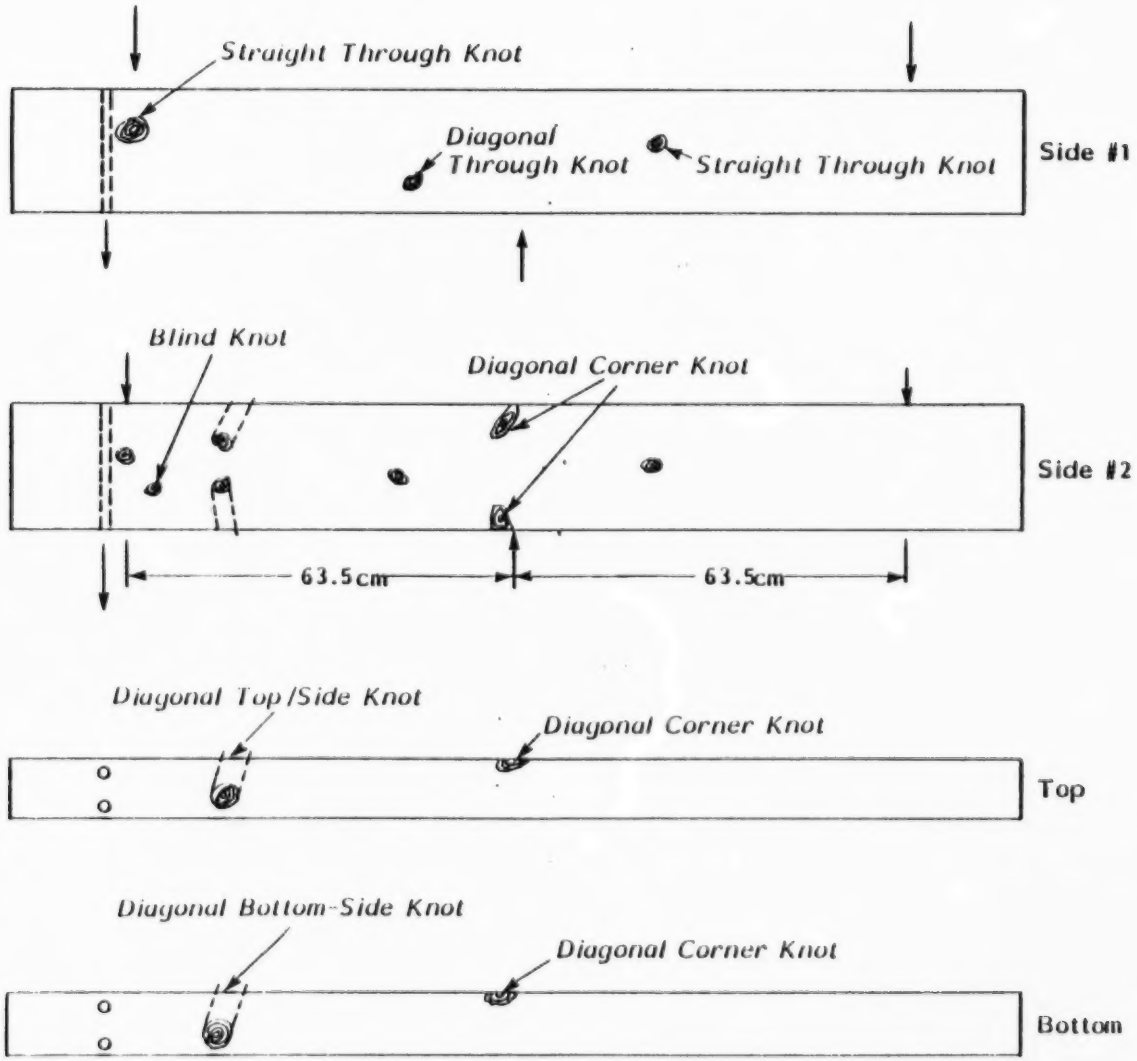


FIGURE 5

SECTION #1 - LOCATION OF THE LOADING POINTS FOR THE 731.52 CROSSARM

168321 RD

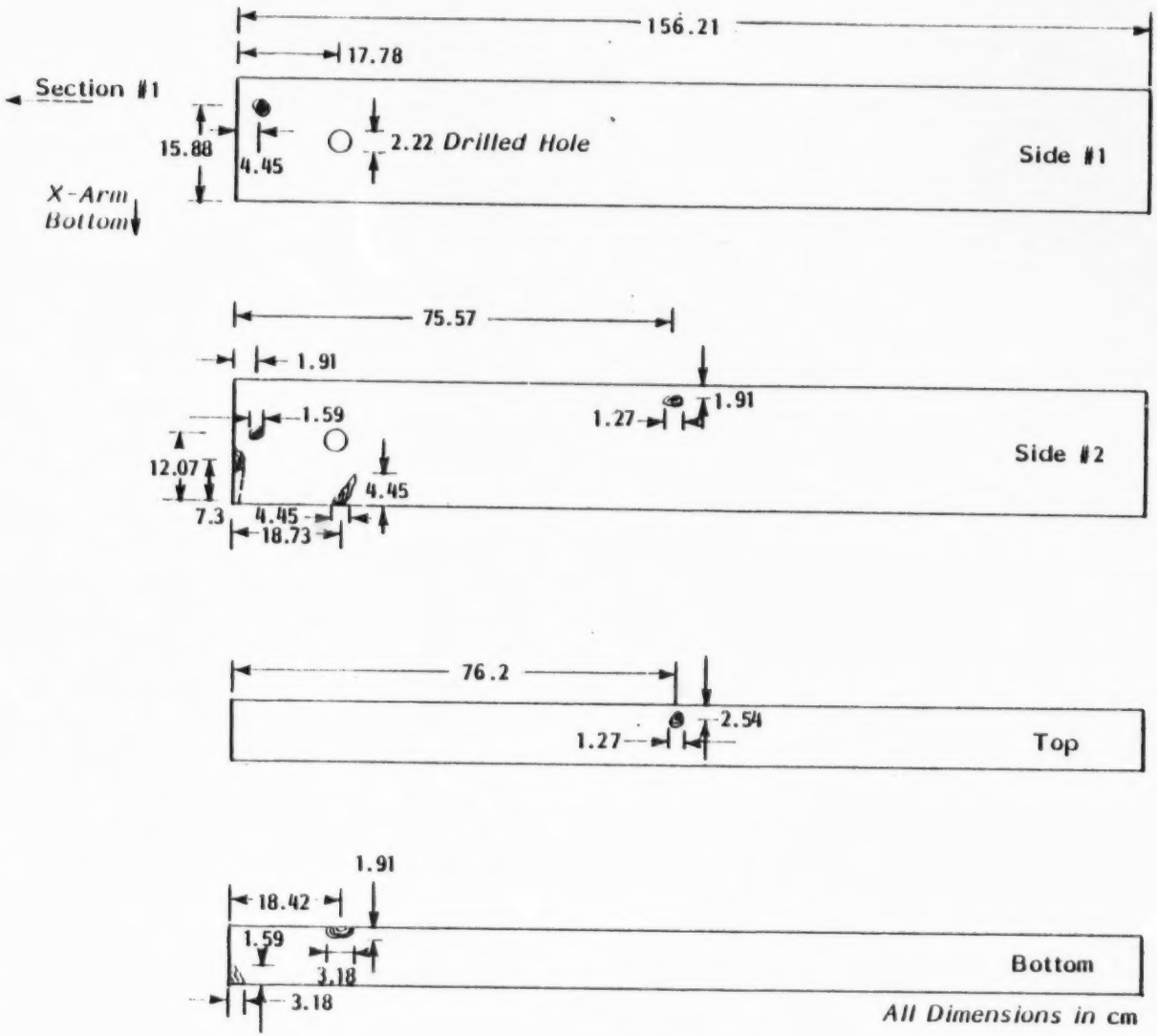


FIGURE 6

SECTION #2 - DIMENSIONS AND KNOT LOCATIONS FOR THE 731.52cm CROSSARM

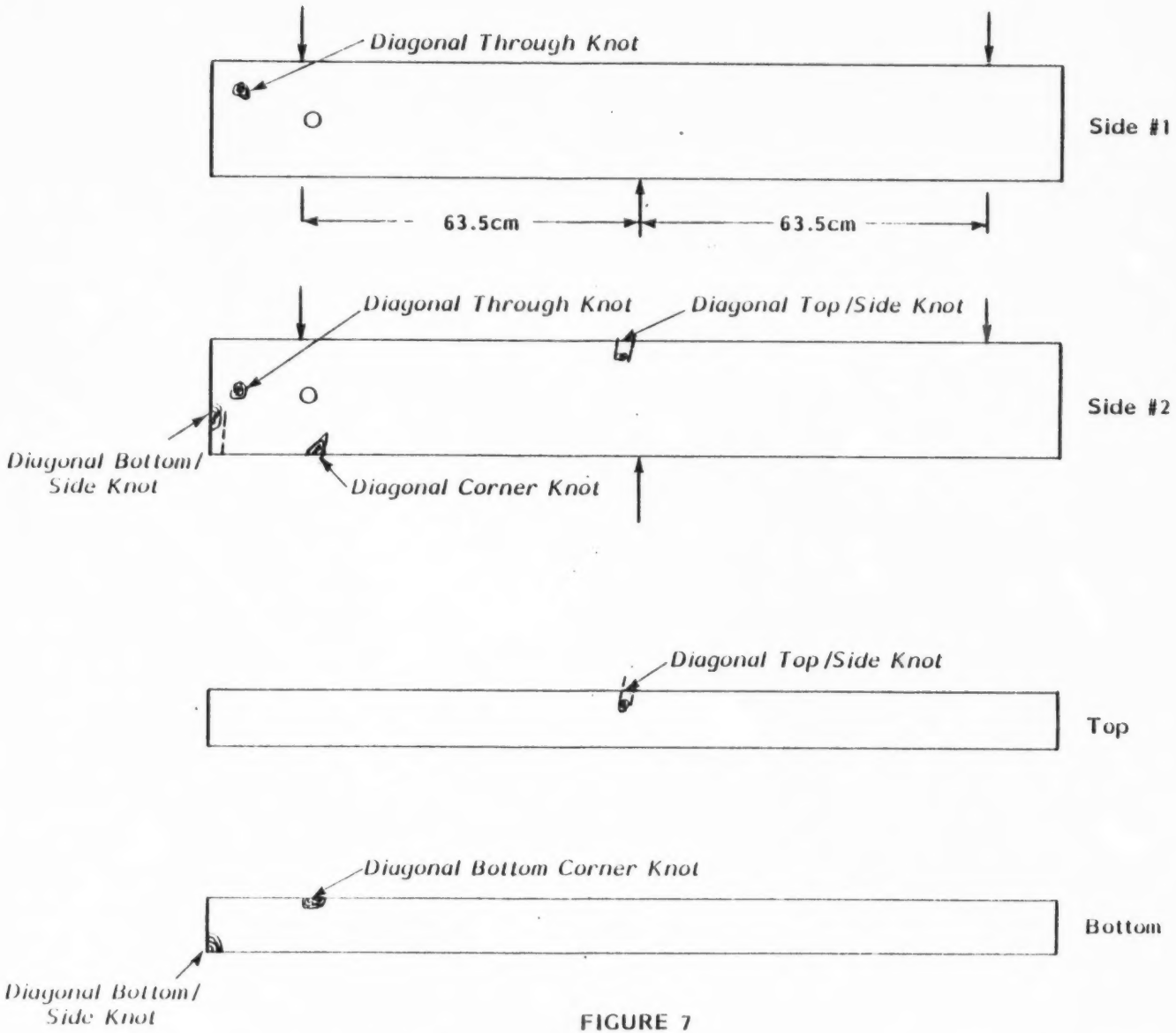


FIGURE 7

SECTION #2 - LOCATION OF THE LOADING POINTS FOR THE 731.52cm CROSSARM

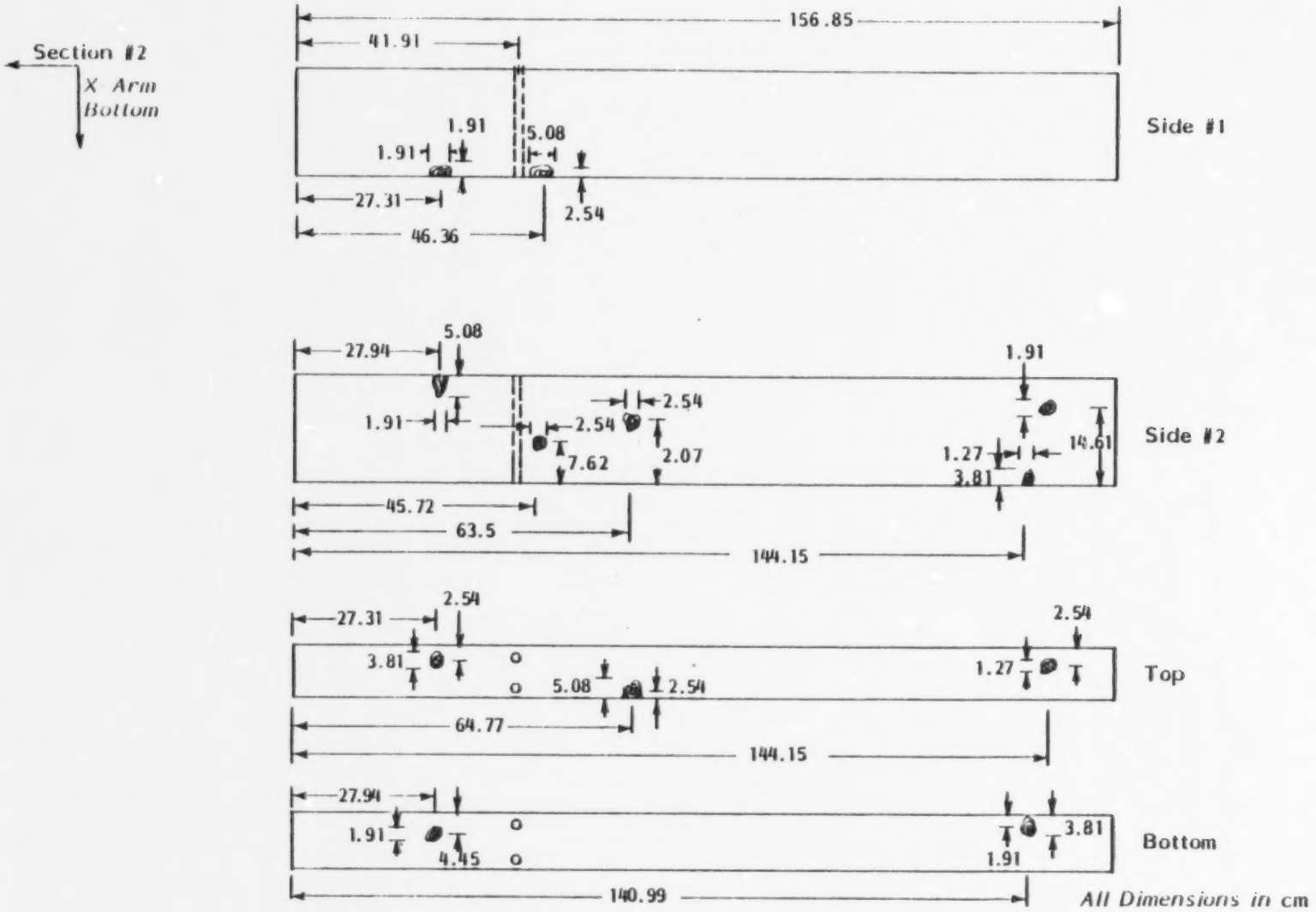


FIGURE 8

SECTION #3 DIMENSIONS AND KNOT LOCATIONS FOR THE 731.52cm CROSSARM

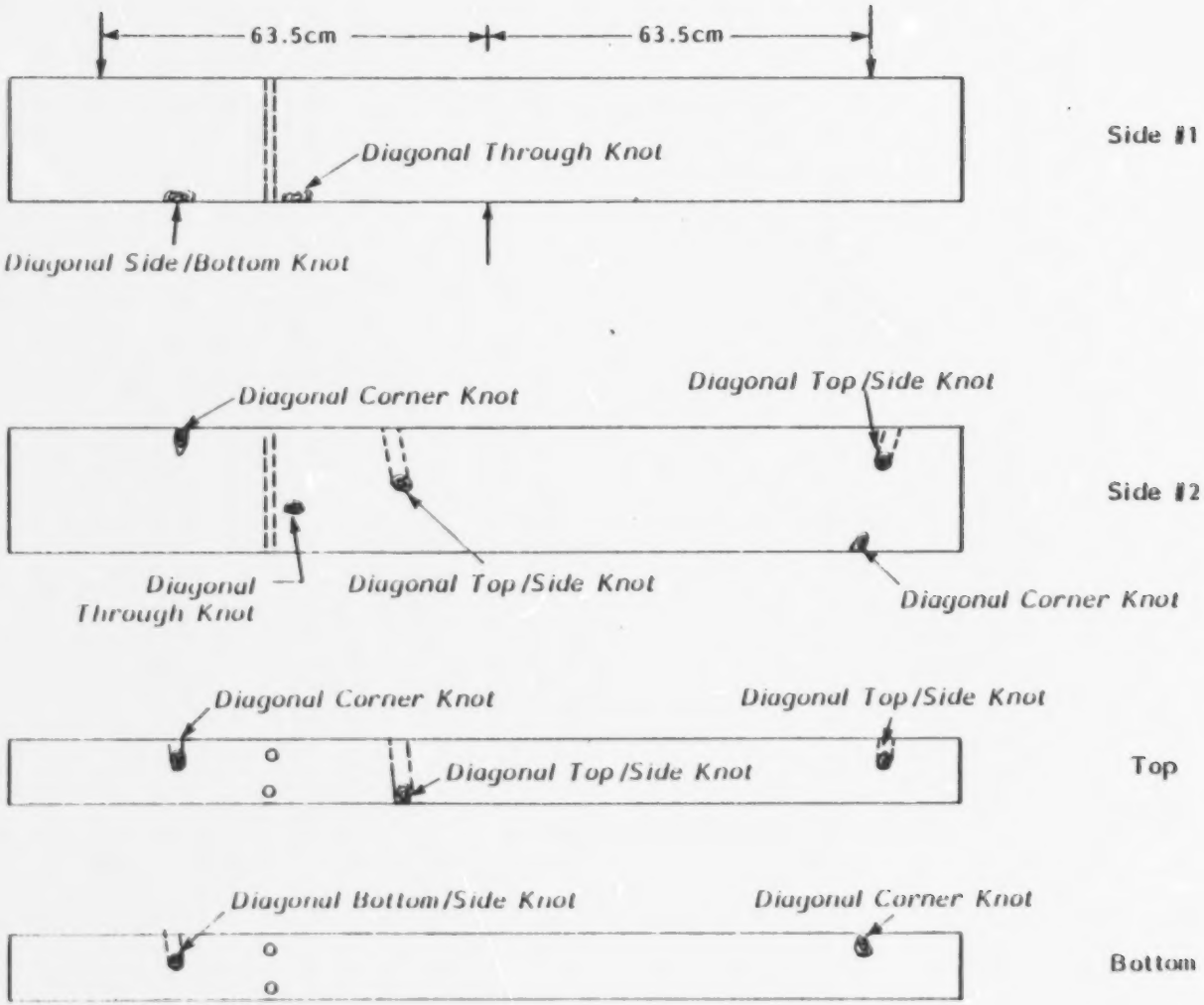
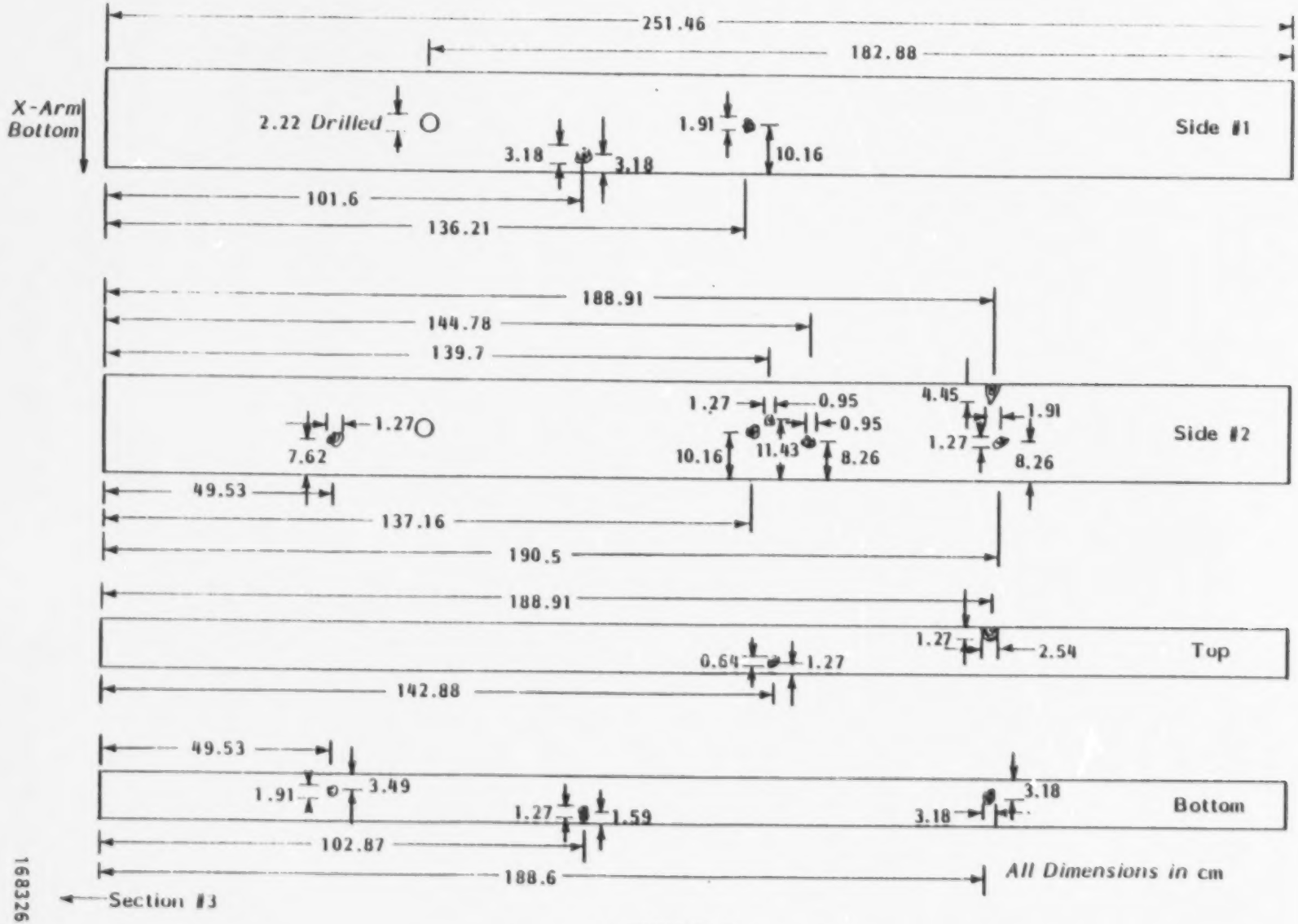


FIGURE 9

SECTION #3 LOADING POINTS FOR THE 731.52cm CROSSARM



168326 RD

FIGURE 10

SECTION #4 DIMENSIONS AND KNOT LOCATIONS FOR THE 731.52cm CROSSARM

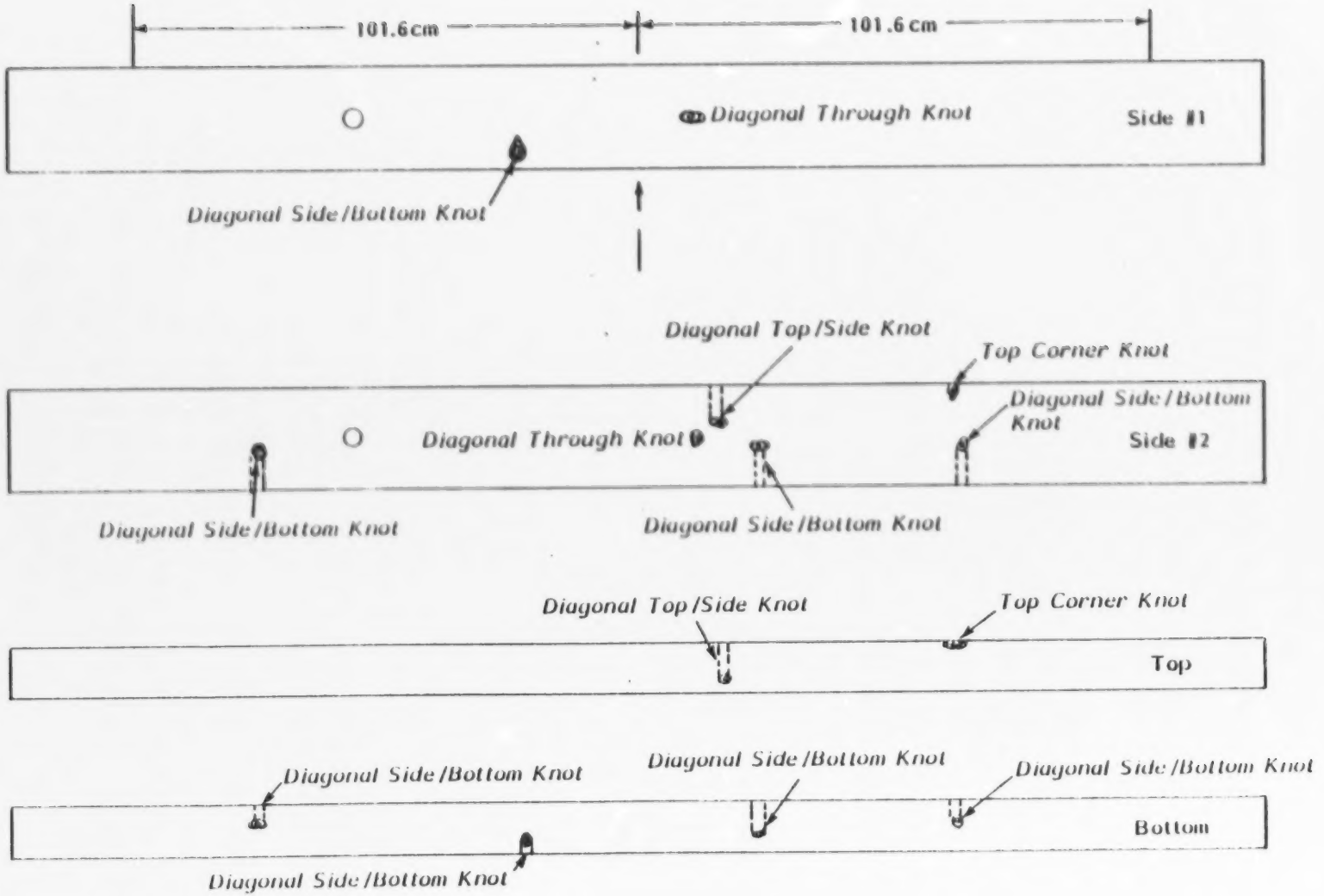


FIGURE 11

SECTION #4 - LOADING POINTS FOR THE 731.52cm CROSSARM

168327 RD

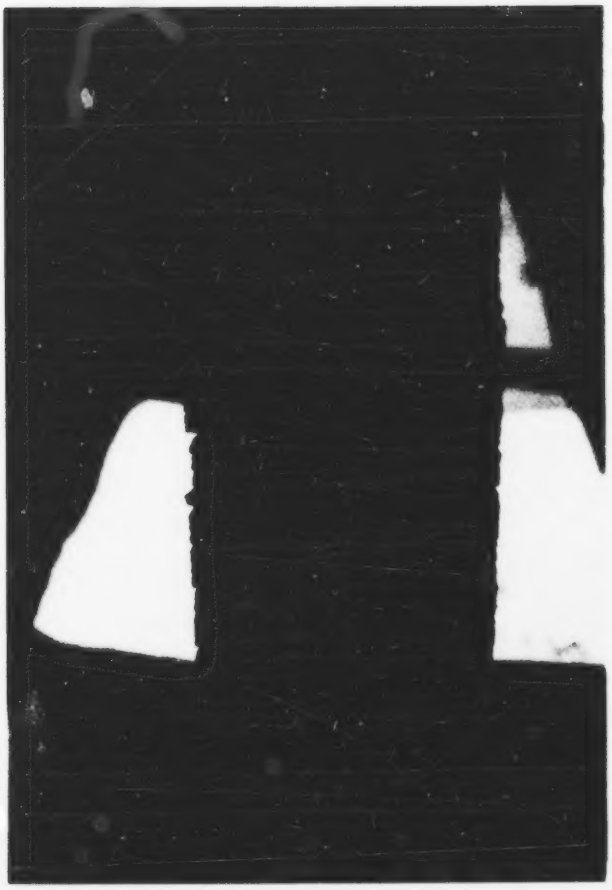


FIGURE 12

Section through 24-foot crossarm, Section 1, showing the surface decay. The sap wood had decayed more than the heartwood. When load tested, failure tended to shear at the large check on the neutral axis (centre of section).

FIGURE 13

Cross section of 24-foot crossarm at Section 2. Surface decay on the right side is greater than the left side. The right side is generally sap wood. The body of the section is in excellent condition.

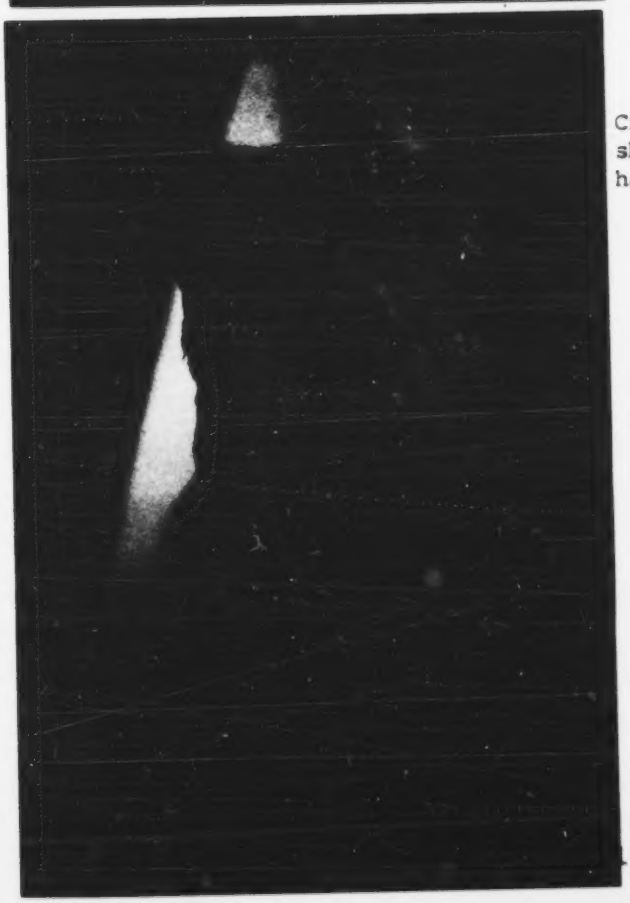


FIGURE 14

Cross section of 24-foot crossarm at Section 3 showing surface decay. The upper right corner has decayed away.

FIGURE 15

Cross section of 24-foot crossarm at Section 4 showing the upper right corner decayed away. The wood appears to be sound within a few millimetres of the surface.

FIGURE 16

Cross section of Sample 2 showing a pocket forming in the top of the arm. In some cases it is possible for water to enter a check on the top of the arm and to create a decay pocket in the arm that is not visible from the top. Also note that the spring wood decays faster than the summer wood (dark growth rings). This gives a sawtooth appearance to the sides of the arm in the picture.

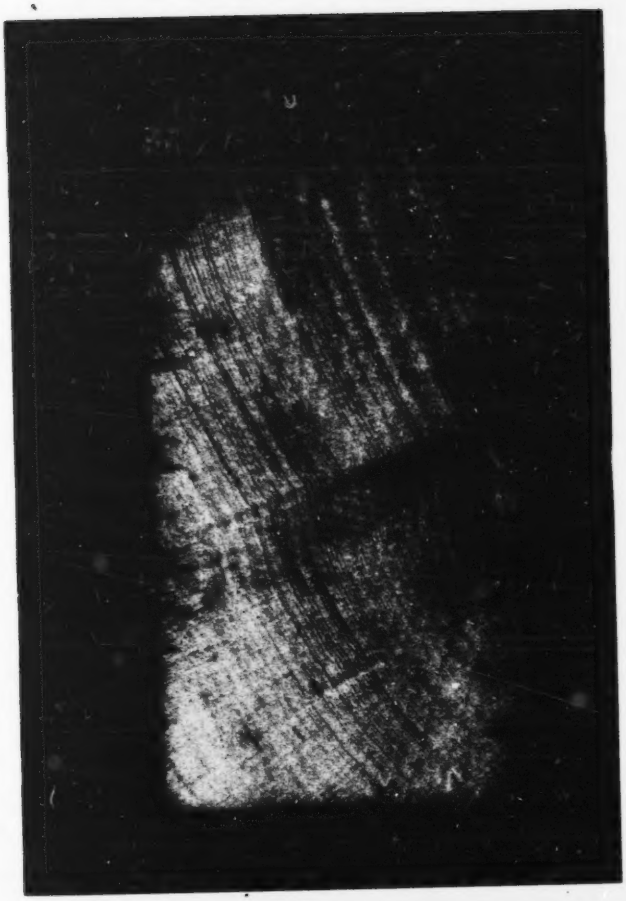


FIGURE 17

End opposite the break in the third sample showing extensive surface decay. The penetrating device went as much as 30 mm into the decay zone at the top of the arm.

FIGURE 18

Section near the break in Sample 3. Considerable decay can be seen at the top. Note how the growth rings tend to disappear about 10 mm from the top of the arm. The zone above the line where the growth rings vanish is brash. The zone below is sound, but with signs of decay penetrating deeper.

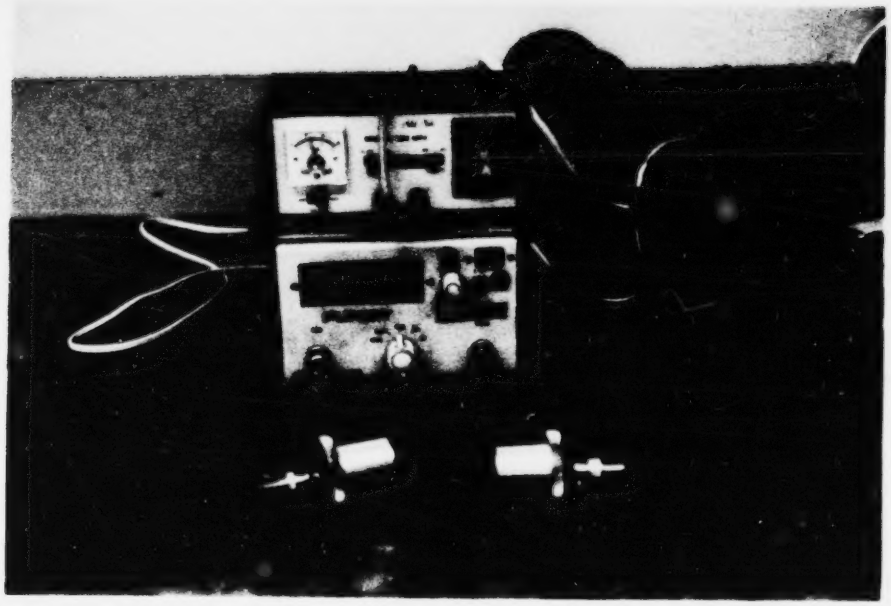


FIGURE 19

Ultrasonic tester used to determine the time it takes for sound waves to travel through the wood. The rough wood surface made the measurement difficult.

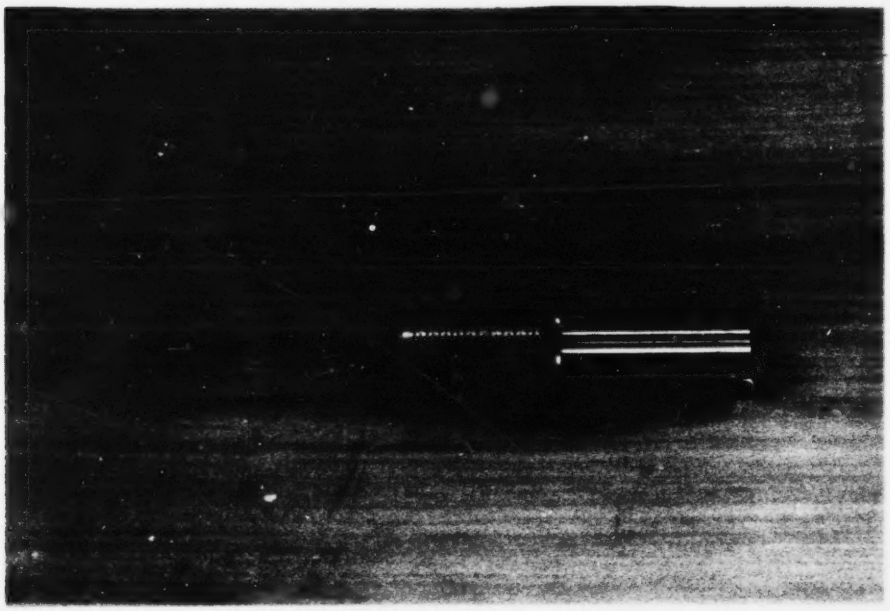


FIGURE 20

Spring loaded penetration device. The scale is used to measure the pressure applied and the sliding brass sleeve measures the depth of penetration.

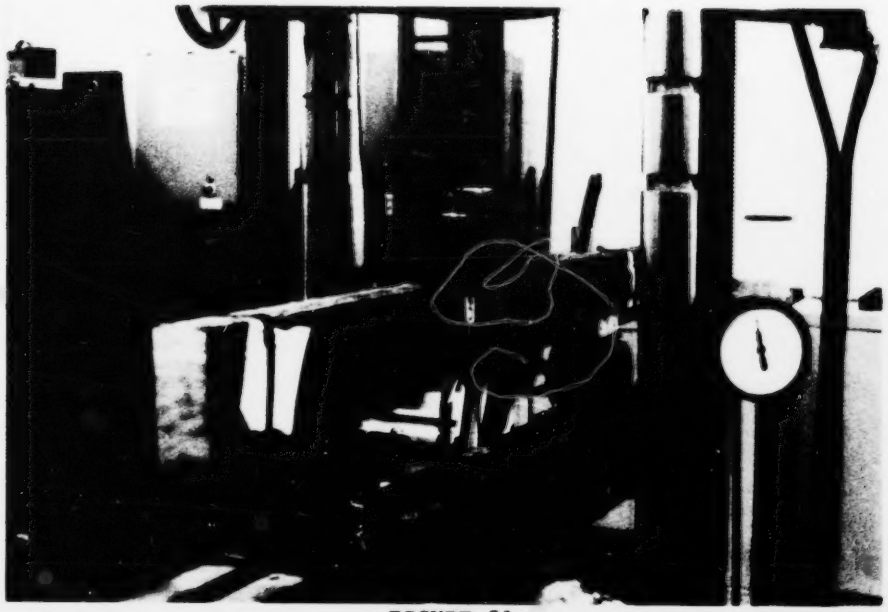


FIGURE 21

Typical setup for strength testing sections of crossarm. The arm was loaded in compression with the top face down. This puts the tension on the top face as it would be in the field. U-shaped metal beam is for measuring the deflection.

FIGURE 22

Typical failure of the crossarm was shear along the neutral axes. This makes determination of the strength of the wood more difficult.